FINAL STATEMENT OF REASONS
FOR
PROPOSED BUILDING STANDARDS
OF THE
DIVISION OF THE STATE ARCHITECT - STRUCTURAL SAFETY

REGARDING THE CALIFORNIA BUILDING CODE, CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 2

The Administrative Procedure Act requires that a Final Statement of Reasons be available to the public upon request when rulemaking action is being undertaken. The following are the reasons for proposing this particular rulemaking action:

UPDATES TO THE INITIAL STATEMENT OF REASONS

The Initial Statement of Reasons for these proposed regulations are updated as follows:

STATEMENT OF SPECIFIC PURPOSE AND RATIONALE

Purpose:

Title 24, Part 2, Sections 1627A, 1629A, 1630A and 1631A, Tables 16A-L & 16A-M.

The proposed changes to Sections 1627A, 1629A, 1630A and 1631A update the requirements used to select analysis procedures for seismic design of irregular structures. The current code language has remained essentially unchanged since the 1989 California Building Code (CBC). It no longer represents the state of the art and results in overly conservative designs in some cases. Additionally, with the addition of near-source effects in the 1997 Uniform Building Code (UBC) model code, the design procedures can produce extremely conservative results.

Under the current provisions, any structure classified as irregular must use the dynamic lateral force procedure. This triggers additional analysis, ground motion, and force scaling requirements. In general, irregular buildings must be designed for 25 to 50 percent higher loads than buildings deemed to be regular. These increases are in addition to those triggered by soil conditions and near source effects.

The most current seismic design guidelines have modified the procedures for irregular structures, in light of experience gained in the 1989 Loma Prieta, 1994 Northridge, and 1995 Kobe earthquakes. Rather than treating all irregular structures the same, current guidelines now consider the effects of irregularities individually. Certain highly irregular structural configurations are no longer permitted for essential buildings in areas of high seismic risk. The proposed changes to Sections 1627A, 1629A, 1630A and 1631A will improve seismic safety and expected performance by restricting the use of highly irregular structural systems, and reduce the cost of construction by updating the design requirements of structures containing common and less severe irregular features.

Title 24, Part 2, Sections 1632A & 1633A.

The proposed changes to Sections 1632A and 1633A are editorial, clarifying detailed structural requirements for piping systems, shear wall boundary elements shared by more than one wall, and elevators.

Title 24, Part 2, Sections 2210A, 2211A & 2213A.

The proposed changes to Sections 2210A, 2211A, and 2213A adopt the latest edition of the American Institute for Steel Construction's (AISC) recommendations for seismic design of steel structures. These recommendations reflect the current state of the art for design of steel structures.

Rationale:

Section 1627A.

A definition for "irregular structure" is being added to Section 1627A. The seismic provisions of Title 24 require that buildings be classified as "regular" or "irregular", based on their configuration. While the types of irregular features are clearly defined, it is only implied that a building possessing one or more of these features is classified as irregular. This proposal clearly defines an irregular structure as one having plan or vertical irregularities.

Section 1629A.8.

This proposal modifies the procedures used to select analysis procedures for seismic design. Section 1629A.8.3 is amended to permit the use of the static lateral force procedure for buildings with reentrant corners, but no other irregularities. The effects of the reentrant corners must still be considered in the design, but their presence does not trigger the use of the dynamic lateral force procedures.

Section 1629A.8.4, Item 2 has been amended to further clarify that, except as permitted by Sections 1629A.8.3 and Section 1630A.4.2, all irregular structures must use the dynamic procedures.

Section 1629A.9.

This proposal amends the limitations placed on the use of irregular structural systems. Buildings with discontinuity in capacity (weak story), severe soft story, and severe torsional irregularity will not be permitted. Structures with these attributes have performed poorly in past earthquakes. The most current seismic design guidelines prohibit these types of irregularities in essential structures in areas of high seismic risk.

Section 1630A.2.2.

This proposal modifies the empirical method for computing building period (Method A), to include near-source effects and an importance factor. Method A is intended to provide a quick, conservative estimate of the period of a structure. It is an empirical method, developed based on period measurements made in structures over a period of years. The vast majority of these measurements were made in commercial-type structures, designed to earlier versions of the building code. However, the equation presently in the CBC fails to recognize that period is directly proportional to the base shear coefficient (unreduced by the R-factor) that is used for design and that this coefficient is significantly larger for essential buildings than for the structures on which the calibration was based. As a result, the Method A period often exceeds the computed Method B period and can result in an unconservative estimate of required strength (if the Method A period is used in lieu of the Method B computation, as permitted by the CBC). This amendment would eliminate this error by making the Method A period proportional to the importance factor and near field factors used in determination of the base shear.

Additionally, in order to address a comment received from Dr. S.K. Ghosh (refer to Comment #1 of this Final Statement of Reasons document) regarding this proposal, DSA is proposing reformatting this section for clarification.

Section 1630A.4.

This proposal amends the simplified, “two-step” approach to the design of structures with vertical combinations of structural systems to permit use of the method for irregular structures. Under current code, the method may only be used when both the rigid base and flexible superstructure are regular. This restriction is not found in the most current seismic design guidelines. The proposed amendments provide the necessary guidance for application of the two-step method to irregular structures.

Section 1630A.7.

This proposal editorially amends the definitions of Δ_{avg}. and Δ_{max} to clarify that interstory drift is checked at each level for application of the amplification factor.

Section 1630A.10.

This editorial proposal clarifies that when exceeding the permissible story drifts, continued operation as well as life safety performance must be considered for essential buildings.

Section 1631A.3.

This proposal amends the Section governing the mathematical model for irregular structures to include the effects of diaphragm stiffness when the building has one or more diaphragm discontinuities. The current CBC does not require explicit inclusion of the effects of these discontinuities, but the entire structure is subject to a minimum increase of 25% to the design lateral load. This amendment would assure that the effects of the diaphragm discontinuities are properly considered in the design.

Section 1631A.5.4.

This proposal amends Section 1631A.5.4 regarding the scaling of elastic response parameters for design. Under the current CBC, all irregular structures must be designed for a minimum of 125% of the base shear determined using the static analysis procedures. In addition, the design base shear cannot be less than V_{sc}, a load scaled to the site-specific spectrum.

This amendment would restrict the application of the 25% base shear increase to buildings with soft stories or mass irregularities, both very undesirable traits. The proposed exception would eliminate the base shear increase for these structures where it can be shown that the change in interstory drifts is minimal. With the introduction of the near field factors, V_{sc}, is no longer needed, since the near source effects are included in the design lateral force. These amendments would bring the CBC into general conformance with other current seismic design guidelines and standards.

Section 1632A.6.

This editorial amendment clarifies the section of the CBC that identifies piping that is exempt from seismic bracing requirements. As currently written, the language implies that all medical gas and vacuum piping must be braced, regardless of size. This amendment clarifies that piping under 1 inch diameter need not be braced. The section has also been amended to clarify that when omitting braces from conduit, the effects of impact on adjacent components must be considered.

*Section 1633A.1 **DSA is withdrawing the proposed amendment to Section 1633A.1 for further study. Refer to Comment #2 of this Final Statement of Reasons document. The original proposed*

amendment was intended to do the following:

Currently, the CBC requires that columns of a structure that form part of two or more intersecting lateral-force-resisting systems trigger consideration of earthquakes acting in a direction other than the principal axes. Shear wall boundary elements are designed to act as columns, resisting axial loads. This proposal editorially clarifies that for the purposes of determining the effects of earthquakes acting in a direction other than the principal axes, a shear wall boundary element is considered equivalent to a column.

Section 1633A.2.13.1.

The California amendments governing the design of elevator components were brought forward from the 1998 CBC to the 2001 CBC. However, at the time, the loads were not modified to reflect that the 1998 CBC was based on allowable stress design, while the basis for the 2001 CBC is strength design. This editorial amendment corrects this oversight by noting that the loads given in this section are at the allowable stress design level.

Table 16A-L.

Table 16A-L has been amended to include the "severe soft story" irregularity. Structures with this very undesirable feature are not permitted in the most current seismic guidelines for essential buildings in high seismic risk areas. In addition, the description of In-plane discontinuity has been clarified.

Table 16A-M.

Table 16A-M has been amended to include the "severe torsional" irregularity. Structures with this very undesirable feature are not permitted in the most current seismic guidelines for essential buildings in high seismic risk areas.

Section 2210A and 2211A.

This amendment updates the seismic design requirements for steel structures to include Supplement 2 of the Seismic Provisions for Structural Steel Buildings, 1997 edition, published by American Institute for Steel Construction (AISC). Supplement 2 represents the latest seismic design criteria for steel structures compatible with the 1997 UBC. DSA amendments to Supplement 1 of the "Seismic Provisions for Structural Steel Buildings", 1997 edition, are brought forward, modified as required to be compatible with the language of Supplement 2. The definition and requirements for inelastic rotation and rapid strength deterioration are retained from Supplement 1.

Additionally, DSA is proposing to amend the original proposed changes to Section 2211A because of conflicting language within the proposal. Refer to Comment #3 of this Final Statement of Reasons document.

Section 2213A.7.6.

This proposal deletes the provisions for use of trusses in special-moment-resistant-frames. The "Seismic Provisions for Structural Steel Buildings" published by AISC do not permit this type of construction in special-moment-resistant-frames.

MANDATE ON LOCAL AGENCIES OR SCHOOL DISTRICTS

The Division of the State Architect has determined that the proposed regulatory action would not impose a mandate on local agencies or school districts.

OBJECTIONS OR RECOMMENDATIONS MADE REGARDING THE PROPOSED REGULATIONS.

COMMENT #1 - DSA/SS 3/02, Sub-Item 4-4

Commenter: Dr. S. K. Ghosh, representing the Portland Cement Association.

Dr. Ghosh expressed a basic concern regarding the derivation of the revised Method A period (CBC, Section 1630A.2.2). While he acknowledged the basic problem, that the Method A period may exceed the computed Method B period, Dr. Ghosh expressed concern that the change in the Method A period computation might arbitrarily force more buildings to be designed to the acceleration-governed region of the response spectra. He suggests that a requirement be added to state that the Method A period cannot exceed the Method B period.

Response:

The computation of Method A period has been historically calibrated to structures in UBC Seismic Zone 4 and is generally a quite conservative estimate of the period of the lateral force resisting system, as compared to the computed Method B period. However, the equation presently in the CBC fails to recognize that period is directly proportional to the base shear coefficient (unreduced by the R-factor) that is used for design. This base shear coefficient is significantly larger for hospital or essential buildings than for the structures on which the calibration was based. As a result, the Method A period often exceeds the computed Method B period and can result in an unconservative estimate of required strength if the Method A period is used in lieu of the Method B computation, as permitted by the CBC.

An essential building is likely to have a lower period than that predicted by the UBC equation for Method A due to the following:

1. The UBC has failed to recognize the shorter period inherent in structures designed for I = 1.5.

2. In drafting the 1997 UBC, the effect of increased design lateral force in near source zones on period was not recognized.

3. Many essential structures are classified as irregular structures. Current regulations require the scaling of base shear to 125% of the static force procedure, resulting in a stiffer structure.

The conclusion that Method A underestimates structure period is supported by analyses of hospital buildings presently being designed in the near-source environment. For example, Eccentric Brace Frame (EBF) buildings designed considering only the action of the design lateral force resisting system and proportioned based on the full drift limit have computed Method B periods less than the computed Method A period, often by a factor 2 or more. This amendment eliminates this error by making the Method A period proportional to the importance factor and near field factors used in the determination of the base shear.

For a drift-controlled structure, period is directly proportional to the base shear coefficient (unreduced by the R-factor), as follows:

1) $T \propto \sqrt{\frac{m}{k}}$, where *T* is the structure period, *m* is the building mass, and *k* the building stiffness.

2) $k = \frac{V}{\Delta}$, where *V* is the design base shear and Δ is the building drift. For a drift-controlled structure, Δ is a constant and independent of the R-factor.

3) $V \propto \frac{IC_v}{T} m$, for structures in the constant velocity portion of the spectrum and neglecting the increased base shear that is prescribed for irregular structures.

4) $T \propto \sqrt{\frac{m\Delta}{V}} \propto \sqrt{\frac{\cancel{m}\Delta T}{IC_v\cancel{m}}} \propto \frac{\Delta}{IC_v}$, by squaring both sides of the equation and dividing by T.

5) Since $C_v \propto N_v$, $T \propto \frac{\Delta}{IN_v}$, hence the value of period computed by Method A, T_A, should be divided by the term IN_v.

For a strength-controlled structure, typically a braced frame or shear wall lateral system, stiffness is also typically directly proportional to strength demand (i.e. brace area, column area or wall area). The period of those structures in the constant acceleration portion of the spectrum is larger than predicted by the proposed equation. However, the complexity of an additional equation was not proposed, since the computed Method A period has no effect on the design of structures that are in this period range.

In order to address Dr. Ghosh's concerns, DSA is proposing to retain the technical substance of the original proposed amendment to Section 1630A.2.2, but reformat it to improve clarity. This is accomplished by the following changes in the proposed language. First, the basic Method A period formula is restored to its familiar, original form. In accordance with a suggestion from Dr. Ghosh, a new paragraph is added to the end of Section 1632A.2.2 Item 1, which states that the Method A period shall not be taken as larger than the Method B period. However, for some structures, designers will not wish to compute the Method B period. Therefore, if the designer does not wish to compute the period using Method B, a requirement has been added that the Method A period is divided by IN_v, in accordance with original proposal.

COMMENT #2 - DSA/SS 3/02, Sub-Item 4-10

Commenter: Dr. S. K. Ghosh, representing the Portland Cement Association.

Dr. Ghosh expressed concern that the proposed amendment to Section 1633A.1 would have the unintended effect of forcing more shear walls into shear controlled behavior, rather than the more desirable flexuraly controlled behavior.

Response:

DSA found this argument to be persuasive, therefore DSA is withdrawing Sub-Item 4-10 for further study.

COMMENT #3 - DSA/SS 3/02, Sub-Item 4-15

Commenter: Kurt A. Schaefer, Deputy Director, OSHPD/Facilities Development Division

As submitted, the proposed amendment to Item 1. Part I, Glossary adds a new definition for Inelastic Rotation of Beam-to-Column Connection. This definition is incorrect and conflicts with the correct definition in S3. In addition, Item 9, S3. DEFINITIONS, as submitted, does not make it clear that the inelastic rotation is represented by the plastic chord rotation angle.

Response:

DSA is proposing to amend this item by deleting the definition of Inelastic Rotation of Beam-to-Column Connection from Item 1. Part I, Glossary. The term "inelastic" is being added to Item 9, S3 DEFINITIONS.

DETERMINATION OF ALTERNATIVES CONSIDERED AND EFFECT ON PRIVATE PERSONS

The Division of the State Architect has determined that no alternative considered would be more effective in carrying out the purpose for which the regulation is proposed or would be as effective and less burdensome to affected private persons than the adopted regulations.

The proposed regulations update the procedures for seismic design of irregular structures by removing needlessly conservative design procedures. These regulations may translate into construction cost savings for public schools and the State's essential services facilities.

PROPOSED ALTERNATIVE(S) THAT WOULD LESSEN ADVERSE ECONOMIC IMPACT ON SMALL BUSINESSES

The Division of the State Architect determined that the proposed rulemaking action creates no adverse economic impact on small business. No proposed alternative(s) were presented to the Division of the State Architect for consideration.

COMMENTS MADE BY THE OFFICE OF SMALL BUSINESS ADVOCATE

No comments by the Office of Small Business Advocate regarding this rulemaking action were received by the Division of the State Architect.

COMMENTS MADE BY THE TRADE AND COMMERCE AGENCY

No comments by the Trade and Commerce Agency regarding this rulemaking action were received by the Division of the State Architect.